GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: July 18, 1980

Project Title: Feasibility Study of Energy Conversion System for Waste Products Utilization

Project No: A-2705 (Sub-project is E-19-621/Roberts/ChE)

Project Director: Mr. Paul H. Butler

Sponsor: Southwire Company; Carrollton, GA 30117

Agreement Period: From 7/16/80 Until 11/15/80

Type Agreement: Standard Industrial Research Agreement, dated July 16, 1980

Amount:

$21,074	A-2705
5,253	E-19-621
$26,327	TOTAL

Reports Required: Final Report

Sponsor Contact Person (s):

Technical Matters

Contractual Matters
(thru OCA)

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TLX 54-2799

Defense Priority Rating: N/A

Assigned to: CMSL/PDG (ChE) (School/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 3/17/81

Project Title: Feasibility Study of Energy Conversion System for Waste Products Utilization

Project No: A-2705 (Sub-project is E-19-621/Roberts/ChE)

Project Director: Mr. Paul H. Butler

Sponsor: Southwire Company; Carrollton, GA 30117

Effective Termination Date: 1/31/81

Clearance of Accounting Charges: 1/31/81

Grant/Contract Closeout Actions Remaining:

- x Final Invoice ~~and Closing Documents~~
- _ Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________

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CA–4 (1/79)

A-2105

B-171-2

FEASIBILITY STUDY
OF
WASTE PRODUCTS ENERGY CONVERSION

AT SOUTHWIRE PLANT

January 30, 1981

Prepared for:

The Southwire Company
Carrollton, Georgia
Contract: P.O. 023681

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332

1981

FEASIBILITY STUDY
OF
WASTE PRODUCTS ENERGY CONVERSION

AT SOUTHWIRE PLANT

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The Southwire Company
Carrollton, Georgia
Contract: P.O. 023681

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology

ABSTRACT

The objective of this project is to evaluate the existing waste wood and other by-products at the Southwire Quadplex in Carrollton and to determine the feasibility of utilizing existing technologies for converting these waste products into other usable energy forms. Specific technologies investigated are:

- Direct Combustion
- Gasification
- Pyrolysis
- Wood to Ethanol Fermentation

The study includes sufficiently detailed investigation into the existing state of the art, as well as significant research advances, in each technology area and prepares a conceptual design of a system for waste energy conversion. This design concept is utilized to develop capital equipment cost and overall system operating costs for use in economic analysis of each conversion system.

Based on the economic analysis and other considerations, the study presents Georgia Tech's recommendations on the best overall solution for the cost effective energy conversion system for implementation at Southwire.

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L I S T O F E X H I B I T S

I. STUDY PERSPECTIVE

Increasing attention and a developing demand on the use of biomass as an indigenous and renewable energy resource is rapidly materializing in the United States. Biomass, including virtually all organic matter whether of plant or animal origin, is a source of biofuels and chemicals and is a substitutable resource for fossil fuels. Of the types of biomass available, wood is the most plentiful and has the highest capture potential.

Since Southwire has an abundance of waste from its processing operations, it is good conservation and management of resources to consider converting the waste into some form of useable energy. The types of material available and the feasibility of conversion are discussed in the first section of this chapter. There are a number of conversion technologies which are commercial or near commercial for the production of fuel from waste. Typical examples are:

- Combustion
- Gasification
- Pyrolysis
- Alcohol Production

A general description of each technology is presented below. In view of these potential opportunities, Southwire has retained Georgia Tech to perform a cost-effectiveness analysis and to recommend a suitable course of action. This chapter concludes with a recapitulation of our approach to this problem.

1. WASTE MATERIALS

Six different types of waste material are available at the plant:

- Wood
- Fluff
- Plastic
- Trash
- Cardboard
- Computer Cards and Paper

Their availability and energy content are summarized in Exhibit I-1. Wood is the most plentiful and is easily converted to energy in any of the processes mentioned. Fluff and trash are available in reasonable quantities, but their heterogeneous nature makes energy conversion a complex proposition. Computer cards and paper, cardboard, and plastic could be converted to energy; however, the small quantities involved coupled with the requirement for size reduction or shredding makes it economically unattractive. Additionally, the paper waste has an existing market providing returns equal to or greater than energy conversion.

Mitsubishi Corporation of Tokyo, Japan, produces a system called the Reverzer which appears to have the ability to convert waste with a high plastic content into useful products. It is currently in use in other parts of the world but not marketed in the United States. The system handles not only mixed scrap, such as polyvinyl chloride, polyethelene, and nylon, but contaminated scrap as well. Typical examples are; used bottles and drums, used polyproplene sacks, cable strippings contaminated with copper, bottles with paper labels, rope and string used for baling the scrap, and sand, mud, broken glass, and other detritus mixed in with the scrap as a result of storage or from other

EXHIBIT I-1
WASTE MATERIAL QUANTITY
AND ENERGY CONTENT

BY-PRODUCT	LBS./DAY	10^6 BTU/DAY
WOOD (WP)	150,000 (DRY)	1,200
"FLUFF"	73,873	933
PLASTIC	6,944	69
TRASH	54,000	459
CARDBOARD	1,000	9
COMP. PAPER & CARDS	179	2
TOTALS	285,996	2,672

sources. It is in this feature, the direct conversion of scrap into useable products, as well as its capacity to handle mixed and contaminated scrap, that this system differs from other plastics recycling systems. The products are mostly replacements for wooden articles and other plastic products. Material produced is less costly than wood, more resistant to fire, resistant to weathering and attack by fungus or insects, and capable of being worked with woodworking tools.

The Reverzer unit consists of a large extruder in which a 75 kW motor drives a 253 mm screw that feeds a fluted conical section with a diameter of 420 mm. The screw serves to melt the material by frictional heat. The melting occurs so rapidly that decomposition is avoided. The cone section delivers the melted material to a 6-liter accumulator. The accumulator has a degassing device for removal of volatiles. A vertical 160 mm screw plunger discharges the material from the accumulator into the mold.

The process is more akin to casting than conventional plastics molding processes. Very low pressure is used, permitting the use of cheap sheet metal molds.

After filling, the molds are conveyed away from the Reverzer unit through a water spray tunnel for cooling, from whence they pass to the mold unloading station. The empty mold returns on the conveyor for filling, with approximately twenty molds kept in circulation. Depending upon the quality and composition of the scrap and the size and shape of the molded parts, production averages between 350 and 500 kg of molded parts per hour.

The only apparent drawback to the Reverzer is its lack of availability. If Southwire is interested in this kind of approach, direct contact with Mitsubishi in Japan may overcome this difficulty.

2. COMBUSTION

More than 230 boilers were sold to burn wood as a primary or alternative fuel source in the U.S. in the period 1965-1975. There are an estimated 2,500 wood-burning boilers operated in the U.S. today, and a sharp expansion in their use is projected. Expanded usage of wood for industrial heating, process steam, electricity generation, and other applications can be accomplished in a number of ways. Two important routes are the purchase and installation of new waste fired boilers and the retrofitting of existing fossil fueled boilers.

3. GASIFICATION

Gasification of waste is its thermal decomposition in the presence of controlled and limited amounts of oxidizing agents, principally air or oxygen, which yields a combustible mixture of gases containing hydrogen, carbon monoxide, and nitrogen as major constituents. The resultant gas also contains lesser amounts of carbon dioxide, methane, and other light hydrocarbons.

When air is used for gasification the resultant product is referred to as low Btu gas, with heating values ranging from 100 to 200 Btu/scf (standard cubic foot). When oxygen is used, medium Btu gas with heating values as high as 350 Btu/scf is produced due to the elimination of the effect of nitrogen dilution.

The basic processes in gasification are similar to those in combustion except that complete oxidation of carbon to carbon dioxide is avoided. In combustion, three basic processes are proceeding simultaneously: drying, volatilization and oxidation of combustible gases, and oxidation of carbonaceous char or residue. In the case of wood gasification, the drying and combustion of char proceed under conditions of controlled temperature and oxygen starvation. The evolved gases contain limited quantities of condensible products, primarily tars. Secondary reactions in the gasifier lead to the formation of hydrogen by the reaction of steam and carbon monoxide and to the formation of carbon monoxide by the reduction of carbon dioxide resulting in increased carbon.

Gasification is an old technology that was displaced by the advent of natural gas and petroleum. Coal was gasified in the nineteenth century. Between 1912 and 1940, almost 600 Crossley gas plants, some still operational, were constructed. Internal combustion engines have been run on this producer gas. In fact, some 700,000 vehicles were adapted in Europe to run on producer gas from portable gasification units developed during World War II.

Wood gasification is not yet a completely proven technology for all applications but its versatility and the many types of gasifiers under development in the United States indicate that widespread application will be achieved in the near term, probably within five years.

4. PYROLYSIS

Pyrolysis, in practice, refers to a thermochemical process whereby biomass is decomposed under starved, but controlled, air oxidation conditions. Theoretically, pyrolysis is accomplished in the absence of oxygen. A small amount of air is introduced to oxidize a fraction of the feedstock thus providing a supply of heat in situ for the decomposition of the remaining material. Unlike gasification reactions, the operating temperature of a pyrolysis reactor is relatively low as in the Georgia Tech/Tech Air Process, although higher temperatures are employed in some systems such as in flash pyrolysis.

Biofuels are produced from wood by pyrolysis in three forms: a carbonaceous char, an oil, and a low Btu gas that may be of medium Btu rating if oxygen or indirect heating is used.

In a pyrolysis process, the gaseous product is generally used to dry the wet feedstock, moisture content being reduced to as low as 5 or 10 percent. The process is normally operated in a manner to maximize the yields of the solid fuel and liquid fuel products. Depending on process type and temperature, oil yields can be manipulated in a range of 1 to 40 percent, and char yields in the range of 10 to 40 percent. Approximately 70 percent of the energy content of the dry input feed is recovered in the char and oil fractions.

The char product is an exceptionally good fuel, possessing a heating value of about 13,500 Btu/lb and low ash and sulfur content. It can be mixed with high sulfur coals to reduce emissions to environmentally acceptable levels. It can be used for the manufacture of charcoal briquettes, or, potentially, a higher valued commodity, activated charcoal.

The pyrolytic oil is a complex mixture of mainly oxygenated organic compounds. It can achieve heating values of 12,000 Btu/lb. In some processes, it contains 15 percent water in a stable emulsion, which facilitates combustion. It can be burned in combination with the char or coal as a slurry, as well. Additionally, the oil has promise as a chemical feedstock.

The low Btu gas must be utilized on site. A portion of the gas is used for drying the input feed while the remainder may be used for firing boilers or even internal combustion engines.

Pyrolysis is a very likely candidate for commercialization in the next decade in those industries where large quantities of forestry and agricultural residues are produced. A recent report indicates that favorable economics apply to pyrolysis and there is a good possibility that there will be an intensification in the development of this technology by governmental and industrial organizations.

5. ALCOHOL PRODUCTION

The national movement to produce gasahol is targeted to meeting a projected U.S. demand of 100 billion gallons for transportation fuel in 1990. This means that 10 billion gallons of ethanol will have to be produced annually by 1990. Unfortunately, it appears that the focus of the national movement is on the conversion of starch food crops, particularly corn, to meet this demand. If corn were to be used exclusively, and a practical yield of 2.5 gallons of anhydrous ethanol per bushel of corn is realized, then 4 billion bushels of corn per annum would be required to meet demands. The record 1979 U.S. crop for corn production was only 7.4 billion bushels. Clearly, neither corn nor other supplemental food crops can be diverted realistically from food to energy use to meet our national thirst for transportation fuel. However, current cellulosic residues in the U.S., at a usage rate of 30 percent of available residues, could provide approximately 7 billion gallons of anhydrous ethanol annually. If energy plantations are developed for biomass conversion according to the U.S. Department of Energy scenario, this quantity of ethanol production could be doubled to 14 billion gallons per annum.

No commercially viable wood-to-ethanol plants exist in the United States at present. Indeed, the technology has received scant attention in much of the last three decades. In recent years, however, there has been an increase in research and development activities principally sponsored by the U. S. Department of Energy.

One major project in the Department of Energy program has led to the design of a novel process which is projected to raise sugar levels to 80 percent as compared to 55 percent conventional yield achieved by conventional dilute acid hydrolysis processes. Process development is being accomplished by Georgia Institute of Technology with the design of a three oven dry ton per day pilot plant which is planned for construction in 1981. Georgia Tech has undertaken an economic analysis which projects that 95 percent ethanol can be produced at selling prices of $1.83/gallon or $1.52/gallon in plants of 1,000 ODT/day or 2,000 ODT/day, respectively, without taking credit for a pristine lignin co-product. These selling prices compare favorably with the current selling price of $1.75/gallon for ethanol from grain. The total capital investment for each plant is projected to be $74 million and $102 million respectively.

6. <u>APPROACH TO THE PROBLEM</u>

To help Southwire select the best conversion process for producing energy from their available waste, Georgia Tech has evaluated the cost and risk of each alternative system as it would be utilized in the Southwire plant at Carrollton, Georgia. A specific application for each process was selected, and an appropriate system designed to meet this need. The resulting designs are described in Section II of this report. Next, the economic viability and apparent risk of each alternative was determined, as outlined in Section III. The concluding section contains our recommended course of action, based on the previous analytical work.

II. SYSTEM DESIGN

Seven alternative systems were designed to convert waste into a useful energy product at Southwire. These alternatives are:

- Wet Cell
- High Pressure Boiler
- Low Pressure Boiler
- Hot Air Turbine
- Gasifier
- Pyrolysis
- Fermentation

The first four are based on direct combustion technology. Each system and its potential application is described in the remainder of this section. In addition, a preliminary cost estimate for purchase and operation of each alternative is presented.

Currently the Southwire Wood Products Division produces approximately 141.25 tons/day of wood by-products. Since the wood products plant operates only five days per week, this amount translates to 100.9 tons/day or 4.2 tons/hour on a seven day week. The wood by-products cannot be considered a free fuel because a portion of these materials is being sold in the open market. The by-products are made up of chips, sawdust, and bark. The wood chips are presently being sold for $9.20/ton and the sawdust has a potential customer willing to pay $6/ton which converts the average value per ton of by-product wood to $7.20/ton. This price will be used in the economic analysis of each proposed wood system.

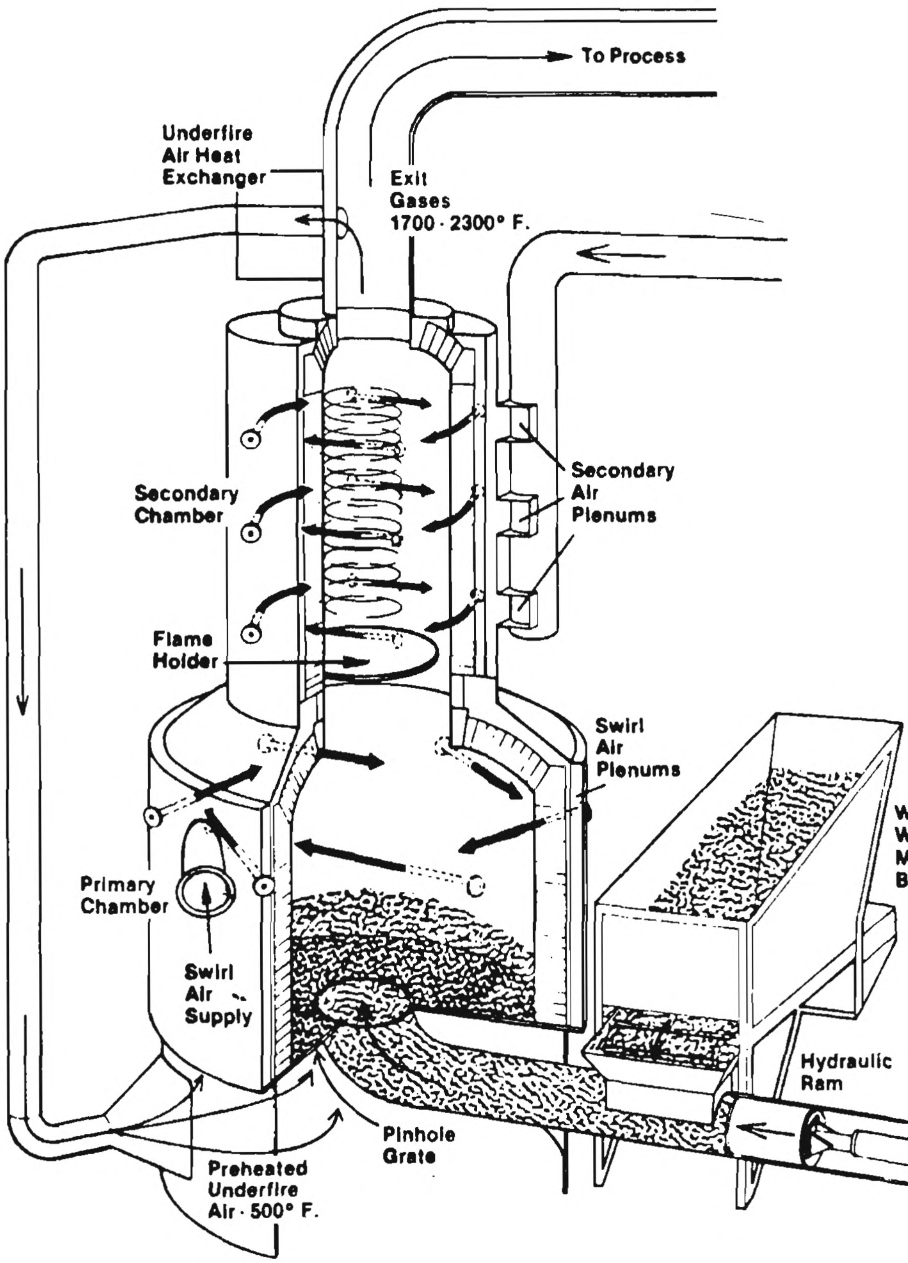
1. ALTERNATIVE IA—WET CELL

Wet cell combustors are a relatively new development in the utilization of waste wood material with the initial commerical installation in 1978. The system was originally conceived to supply heat for dry kiln or veneer drying applications but in 1980 a wet cell was installed to fire a lime kiln. The first wet cell combustor was designed and developed by Lamb-Cargate Industries of New Westminster, British Columbia. Lamb-Cargate offers wet cell combustors in output ratings of 25, 45, 60, 75, 100, and 150 million Btu/hr. Units are sold complete from the inlet metering bin through the outlet, including the fuel feed system, combustor and controls. A spin-off company, Heuristic Engineering, located in Vancouver, British Columbia, also offers a combustor similar to the wet cell in smaller sizes starting at 100,000 Btu/hr output.

The Southwire aluminum furnaces present a unique application for the utilization of by-product wood. There are three melting furnaces in the west mill, two rated at 20 MMBtu/hr and one at 15 MMBtu/hr. A wet cell combustor or its equivalent would be an appropriate system to convert the wood to a usable hot gas. This unit, illustrated in Exhibit II-1, is similar to a close coupled wood gasifier and is capable of generating 2000°F hot gases from 50% moisture content wood. The particulate loading in the output gas stream is relatively low as a consequence of the underfeed stoker and the multistage combustion air addition, and should not pose a contamination problem to the metal being melted.

There are some logistics problems encountered in the placement of the wet cells due to the location of the melting furnaces at the Southwire plant. The only practical location for the wet cell is south of the west mill just inside the

EXHIBIT II-1
WET CELL



building. This placement will allow no room for fuel storage. The fuel would have to be stored in an open area near the railroad tracks shown in Exhibit II-2 and conveyed approximately 350 feet to the combustor. A physical arrangement such as this is possible, but because of the high cost of conveying it usually is not practical.

Budget cost estimates for the system are shown in Exhibit II-3 and II-4. These costs include two wet cells rated at 20 MMBtu/hr output each, 350 feet of belt conveyor, and a 375-ton capacity storage silo. A line drawing of this proposed system is shown in Exhibit II-2. A natural gas price of $3.00/MCF was used in all of the economic evaluations. The projected gross savings from this conversion is $420,955 per year with a simple payback of 1.67 years. Net savings after deducting capital repayment is approximately $280,682 per year, using a ten year life and 15 percent interest rate. Since the Wood Products Division's available supplies are only 36,725 tons/year and 41,983 tons/year are required, Southwire would have to purchase approximately 5,000 tons of fuel per year. By choosing to convert one 20 MMBtu/hr furnace and a 15 MMBtu/hr, this purchase requirement could be effectively eliminated.

2. ALTERNATIVE IB—HIGH PRESSURE BOILER

The east and west mills have a combined steam demand of 20,000 lb/hr. This steam is generated by a natural gas package boiler with energy recovery equipment and an identical boiler serves as a backup. The approach investigated was to replace the gas boiler with a high pressure watertube wood boiler as shown in Exhibit II-5. The high pressure steam generated at 600 psi, 750°F could be reduced to the 275 psi header pressure through a turbine and the power derived could replace an existing electric motor in the Southwire plant. Because of the

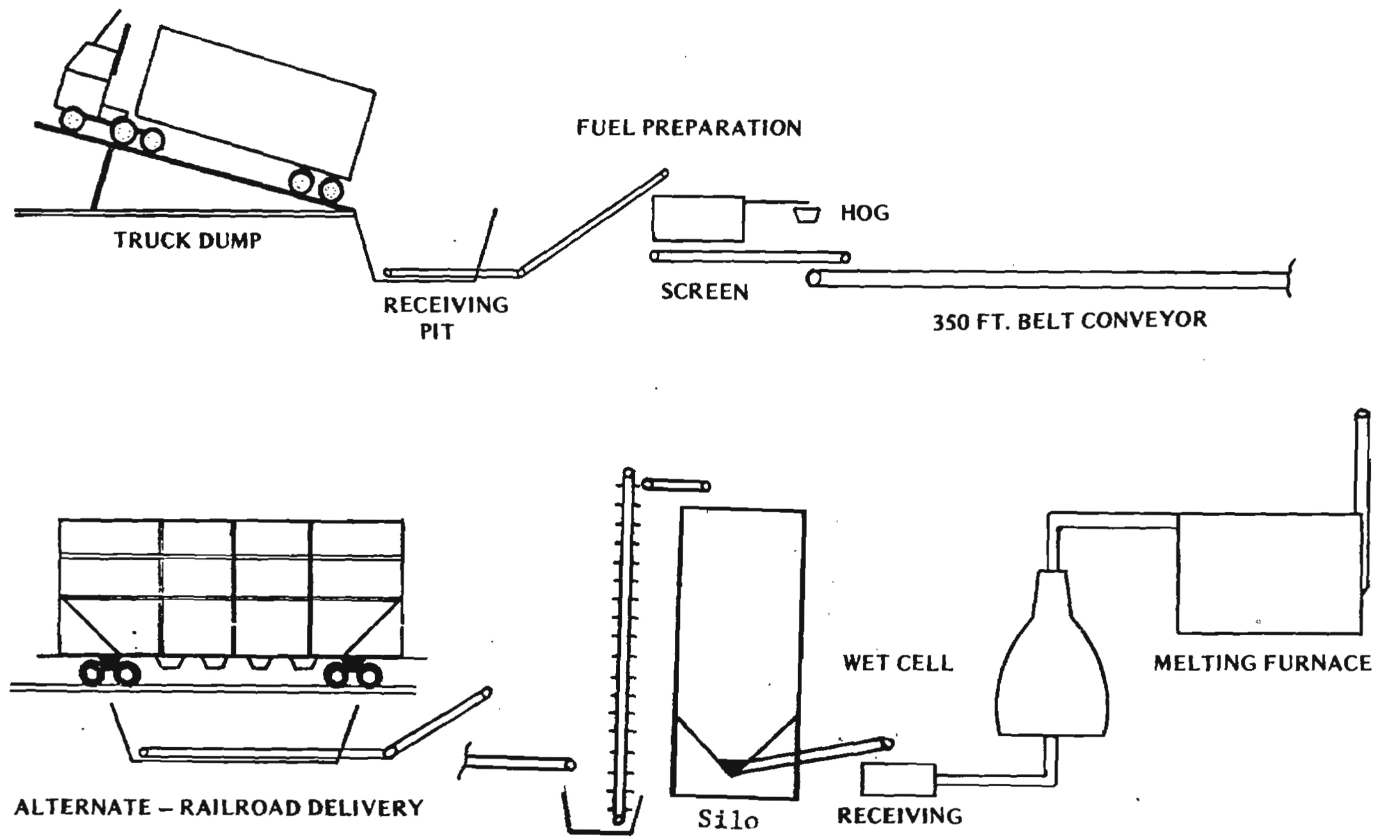


EXHIBIT II-2
WET CELL SYSTEM

EXHIBIT II-3
WET CELL CAPITAL INVESTMENT

Purchased Equipment	
2 Wet Cell burners 20 MMBtu/hr	$220,500
Hot air piping	$ 4,000
Truck unloader	$ 50,000
Wood conveying, 250 ft belt conveyor	$ 40,000
Storage silo	$ 40,000
	$354,500
Construction	
Piping and mechanical	$ 30,000
Electrical	$ 19,000
Service facilities	$ 77,000
Instrumentation & controls	$ 17,500
Yard improvement	$ 25,000
	$168,500
Indirect Cost	
Engineering	$ 64,000
Construction expenses	$ 76,000
Total direct & indirect	$663,000
Contractor fees	$ 33,000
Contingency	$ 66,000
Fixed capital investment	$762,000
Working capital	$118,000
TOTAL CAPITAL INVESTMENT	$880,000
20% Federal Tax Credit	$176,000
NET CAPITAL INVESTMENT	$704,000

EXHIBIT II-4
WET CELL ECONOMIC ANALYSIS

Operating Cost	
Raw material (41,983 tons of wood @ $7.20/ton)	$302,278
Labor	$ 25,000
Supervision & clerical	$ 15,000
Utilities	$ 40,000
Maintenance & repair	$ 40,000
Operating supplies	$ 5,000
	$427,278
Direct Production Cost	
Fixed charges	$ 17,100
Plant overhead	$ 51,300
TOTAL ANNUAL PRODUCTION COST	$495,678
Estimated cost of conventional system	$916,633
Gross Annual Savings	$420,955
Loan Repayment	$140,273
NET ANNUAL SAVINGS	$280,682

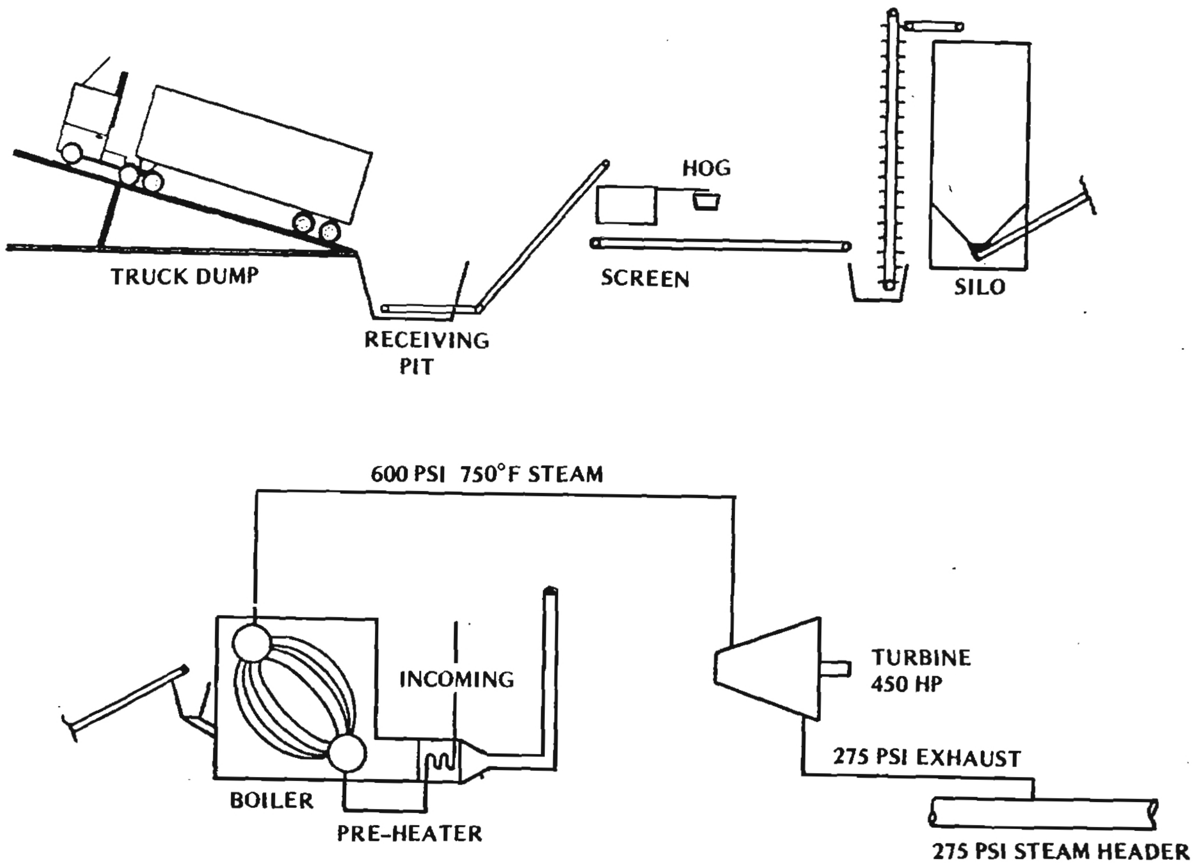


EXHIBIT II-5
HIGH PRESSURE BOILER SYSTEM

high pressure, a watertube design would be required. Due to the high degree of field erection with watertube boilers, their cost is higher than a firetube boiler of comparable size. An estimate of system costs is shown in Exhibits II-6 and II-7. Included in the system costs are the boiler, fuel receiving and handling, fuel storage, wet scrubber, and steam turbine.

The turbine in this system would replace an electric motor driving the plant air compressor. A 450 hp turbine, equal in size to the average demand of the current electric motor, was selected. With the prescribed entry and exit conditions a heavy duty single stage turbine is required due to the possibility of erosion problems caused by liquid droplets in the steam. Because of the low efficiency and small pressure drop available, the turbine can only produce 278 hp at 20,000 lb/hr. This output is based on the manufacturer's estimated steam rate of 72 lb/hp-hr. Performance and cost information for the steam turbine was supplied by the local Terry Turbine representative.

There could be some location problems with this arrangement of equipment. Since there is no space near the air compressor for placement of the boiler, the compressor would likely have to be relocated. As discussed above, at design output conditions the turbine could supply only 278 of the 450 horsepower needed. The turbine could supply all the power required by the compressor if the back pressure in the header were lowered to about 100 psi or the steam flow was increased to 32,000 lb/hr.

A cost of $3.00/MCF was used for gas with the conventional system. Again, the required amount of wood slightly exceeds that produced at the Wood Products Division. The amount that will have to be purchased is about 455 tons/year. By combining the fuel and electrical savings from this arrangement, the gross savings is $285,899 yearly or a payback period of 3.24 years.

EXHIBIT II-6
HIGH PRESSURE BOILER
CAPITAL INVESTMENT

<u>Purchased Equipment</u>	
Boiler	$ 370,000
Pollution control-wet scrubber	$ 37,000
Boiler house	$ 15,500
Silo	$ 50,500
Truck dump	$ 77,000
Steam turbine-450 hp	$ 46,000
	$ 596,000
<u>Construction</u>	
Piping & mechanical	$ 12,800
Electrical	$ 8,000
Service facilities	$ 32,000
Instrumentation & controls	$ 8,000
Yard improvement	$ 10,400
	$ 71,200
<u>Indirect Cost</u>	
Engineering	$ 85,000
Construction expenses	$ 100,000
<u>Total direct & indirect</u>	$ 852,200
Contractor fees	$ 44,000
Contingency	$ 87,000
<u>Fixed capital investment</u>	$ 983,200
Working capital	$ 176,800
<u>TOTAL CAPITAL INVESTMENT</u>	$1,160,000

EXHIBIT II-7
HIGH PRESSURE BOILER
ECONOMIC ANALYSIS

<u>Operating Cost</u>	
Raw material (fuel 37,147 tons of wood @ $7.20/ton)	$267,458
Labor	$ 25,000
Supervision & clerical	$ 15,000
Utilities	$ 40,000
Maintenance & repair	$ 40,000
Operating supplies	$ 5,000
<u>Direct Production Cost</u>	
Fixed charges	$ 16,000
Plant Overhead	$ 48,000
TOTAL ANNUAL PRODUCTION COST	$456,458
Estimated cost of conventional system $/yr (Natural gas @ $3.00/Mcf) (Electricity @ $0.35/Kwh)	$742,357
GROSS ANNUAL SAVINGS	$285,899
Loan Repayment	$184,906
NET ANNUAL SAVINGS	$100,993

3. ALTERNATIVE IC—LOW PRESSURE BOILER

The third option considered was a low pressure firetube boiler. Though unable to produce high pressure steam for power generation, this system can replace the existing natural gas boiler. A horizontal return tube (HRT) boiler was selected for this analysis because it is the most economical choice. Exhibit II-8 shows the equipment required for this installation. The cost estimate for this option is shown in Exhibits II-9 and II-10. The overall system is much lower in cost than the watertube boiler because it is simpler, requires less field erection, and does not include a turbine. Compared to a conventional gas fired boiler with gas at $3.00/MCF the low pressure wood boiler has gross savings of $303,800/year and has a simple payback period of 1.99 years.

Their history goes back many years and numerous HRT installations in operation since the early 1900's can be found in older textile plants. The boilers can burn green wood if designed with a dutch oven furnace. Typical efficiencies are on the order of 65%. There are several manufacturers of wood fired HRT boilers for industry. Two companies close by are Industrial Boiler of Thomasville, Georgia, and Applied Engineering of Orangeburg, South Carolina. Many of these units have recently been installed in forest product plants with a readily available wood supply.

4. ALTERNATIVE ID—HOT AIR TURBINE

The final direct combustion option considered was the use of wood as a fuel source for a gas turbine. Unlike other arrangements, this system would be placed at the Wood Products Division thereby eliminating the problems and costs associated with fuel transportation. The system will utilize waste wood to produce electricity and thermal energy for lumber drying. The system was sized so as to use all of the available wood waste. To calculate turbine output, a 39% thermal efficiency was used.

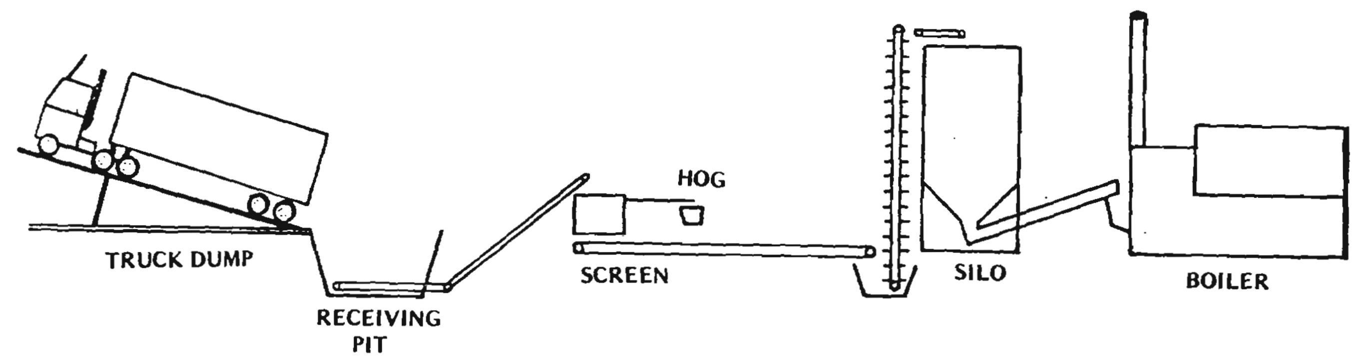


EXHIBIT II-8
LOW PRESSURE BOILER SYSTEM

EXHIBIT II-9
LOW PRESSURE BOILER
CAPITAL INVESTMENT

Purchased Equipment	
Boiler--20,000 lb/hr HRT	$250,000
Boiler house	$ 10,000
Fuel Preparation	$ 10,000
Truck dump	$ 50,000
Fuel handling	$ 12,500
Foundation	$ 7,500
	$340,000
Construction	
Piping and mechanical	$ 20,000
Electrical	$ 12,000
Service facilities	$ 55,000
Instrumentation & controls	$ 10,000
Yard improvement	$ 17,500
	$114,500
Indirect Cost	
Engineering	$ 55,000
Construction expenses	$ 64,800
Total direct & indirect	$574,300
Contractor fees	$ 28,000
Contingency	$ 56,700
Fixed Capital Investment	$659,000
Working capital	$ 97,000
TOTAL CAPITAL INVESTMENT	$756,000

EXHIBIT II-10
LOW PRESSURE BOILER
ECONOMIC ANALYSIS

Operating Cost	
Raw material (32,262 tons of wood @ $7.20/ton)	$264,400
Labor	$ 19,500
Supervision & clerical	$ 15,000
Utilities	$ 33,000
Maintenance & repair	$ 33,000
Operating supplies	$ 5,000
	$336,900
Direct Product Cost	
Fixed charges	$ 12,100
Plant Overhead	$ 36,300
TOTAL ANNUAL PRODUCTION COST	$385,300
Estimated cost of conventional system (Natural gas @ $3.00/Mcf)	$689,100
GROSS ANNUAL SAVINGS	$303,800
Loan Repayment	$120,508
NET ANNUAL SAVINGS	$183,292

Sizing of the kilns was accomplished by estimating the amount of energy required to evaporate all the water in green wood and comparing this to the available thermal energy. On this basis, three 50,000 board foot kilns can be heated with turbine exhaust. The proposed facility layout is shown in Exhibit II-11. A wet cell wood burner supplies 1600°F atmospheric pressure gas to a sub-atmospheric turbine. A schematic of the sub-atmospheric cycle is presented in Exhibit II-12. The entering gas expands through the turbine to approximately 4 psi. Heat is transferred to the incoming air stream in the recuperator. Further heat is removed in a heat sink before the gases are compressed to atmospheric pressure for exhaust. The sub-atmospheric cycle is preferred over a conventional gas turbine cycle for several reasons. First, almost all of the high efficiency wet wood burners are designed for atmospheric pressure. This is unacceptable for direct use in conventional turbines but well suited to the sub-atmospheric turbine. Also, since the sub-atmospheric turbine working fluid is below atmospheric pressure, the turbine components are larger and sturdier which limits solid particle erosion problems usually associated with solid fuel firing. An added advantage is that hot air leaving the recuperator can be used for low temperature heating such as a lumber kiln. The budget cost estimates for a system to utilize 100% of Southwire's wood waste are presented in Exhibit II-13. The turbine system, assumed to cost $500 per kW, makes up the largest part of the capital cost. This cost includes the turbine, generator, heat transfer and electrical equipment. The system is sized to operate continuously consuming 4.2 tons per hour of wood and to produce 4300 kW of electricity. Because the system is assumed to be located at the Wood Products Division, waste heat from the turbine exhaust will contain sufficient energy to heat three 50,000 board foot kilns.

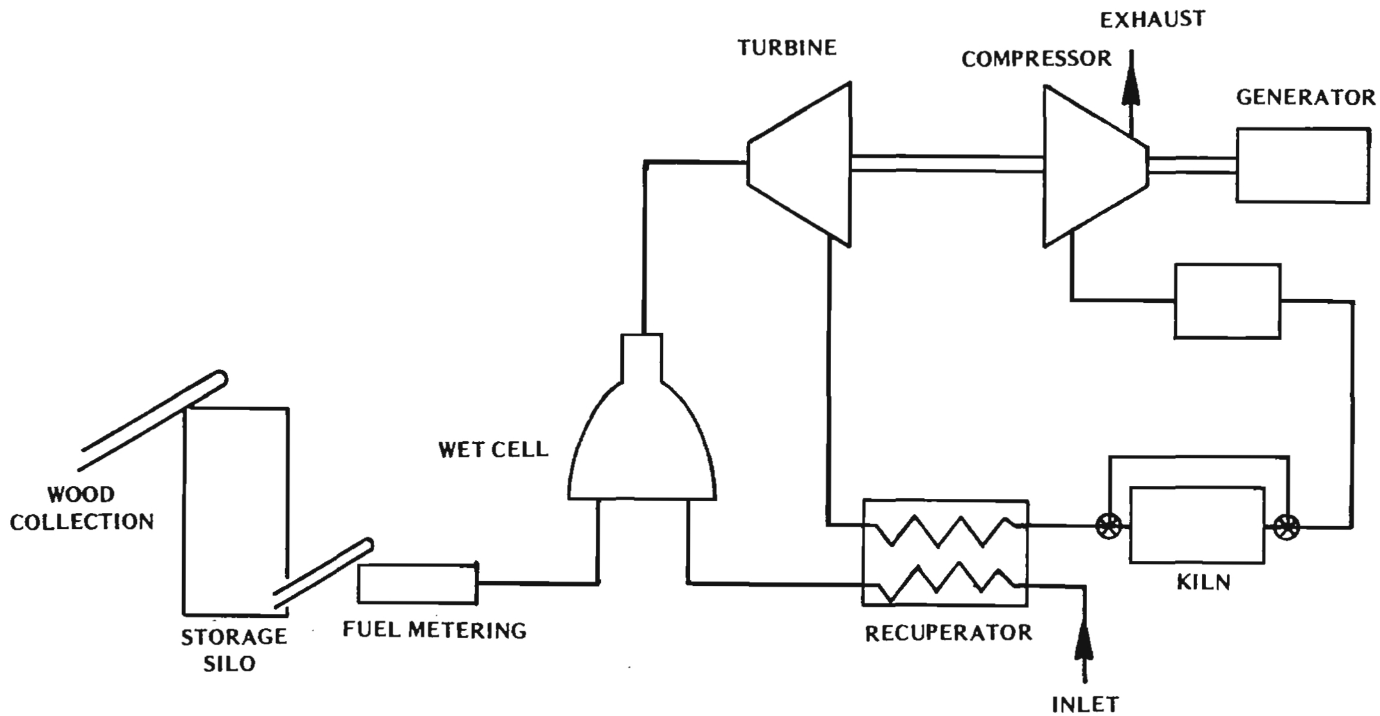


EXHIBIT II-11
HOT AIR TURBINE SYSTEM

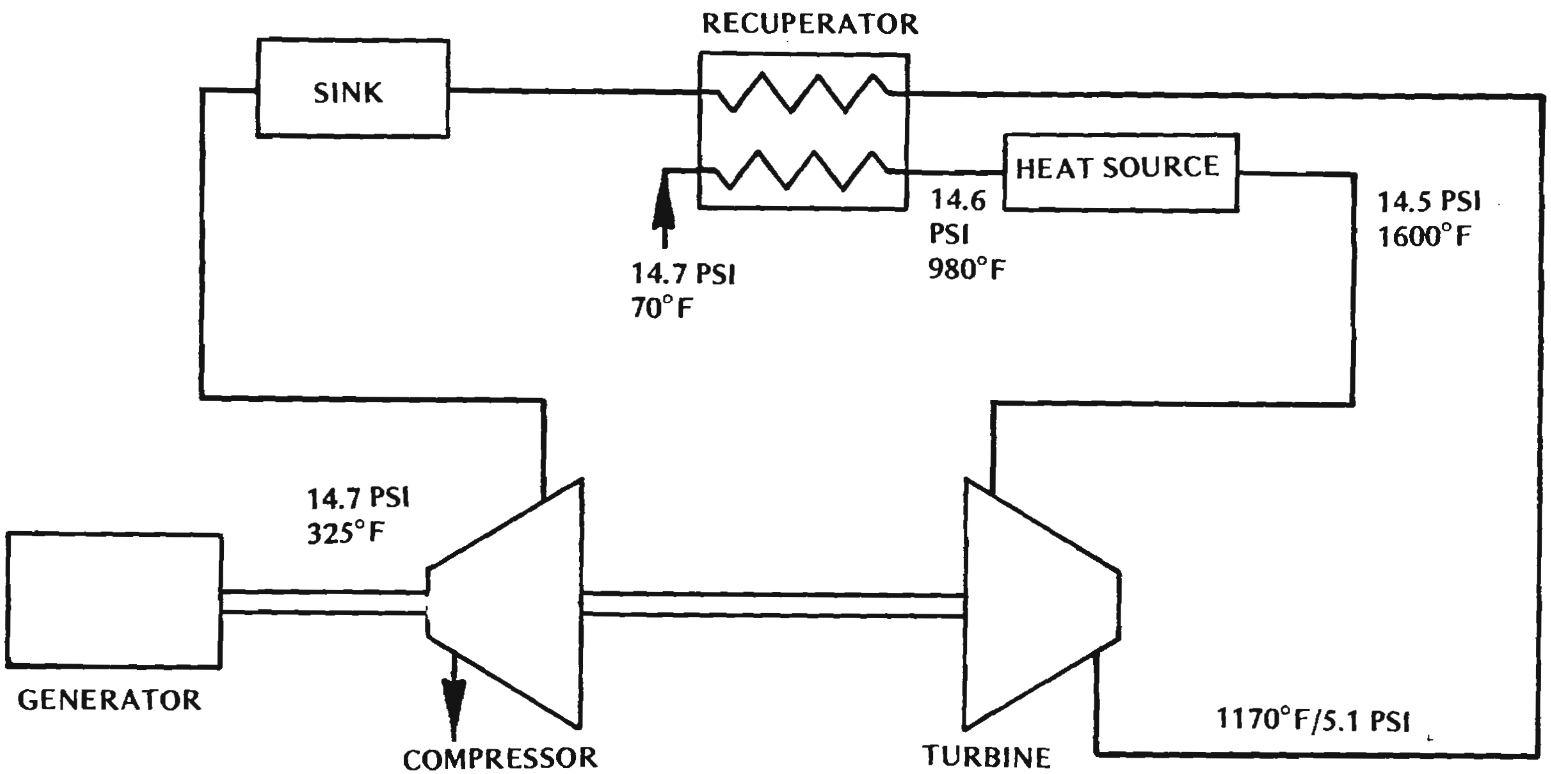


EXHIBIT II-12
HOT AIR TURBINE SCHEMATIC

EXHIBIT II-13
HOT AIR TURBINE
CAPITAL INVESTMENT

Purchased Equipment	
Wet Cell burner (40 MMBtu/hr)	$ 292,760
Gas Turbine (4300 Kw)	$1,074,520
Storage Silo	$ 50,640
Dry kiln (3 @ 50,000 bft)	$ 164,580
	$1,582,500
Construction	
Piping and mechanical	$ 93,000
Electrical	$ 55,850
Service facilities	$ 256,000
Instrumentation & controls	$ 46,540
Yard improvement	$ 81,540
	$ 532,930
Indirect Cost	
Engineering	$ 256,000
Construction expenses	$ 301,600
Total Direct and Indirect	$2,673,030
Contractor fees	$ 130,320
Contingency	$ 263,900
Fixed Capital Investment	$3,067,250
Working capital	$ 97,840
TOTAL CAPITAL INVESTMENT	$3,165,090
20% Federal Tax Credit	$ 633,018
NET CAPITAL INVESTMENT	$2,532,072

The wet cell burner is the same device considered earlier for use with the aluminum furnaces. This combustor was selected because of its low particulate emissions, measured to be approximately .06 grams/scf, and its ability to generate high temperatures suitable for turbine firing even with green wood fuel. The sub-atmospheric turbine is a new development from Garrett Industries, Los Angeles, California. The first sub-atmospheric turbine which generates 12 hp was used to drive a heat pump. Another unit currently under development to recover energy from the high temperature exhaust of a glass furnace produces 300 kW of electricity. Preliminary sizing on a 10 Megawatt system has been completed. The turbine wheel diameter for this unit is approximately 8.5 feet. Preliminary concepts for the Southwire system envision a modular design with three or more small turbines each firing a separate kiln.

Data on lumber kilns was collected from the Irwinton-Moore Company. Costs for a 50,000 board foot indirectly heated package kiln including installation were found. Further study on the matching of the turbine exhaust to the kilns must be made before finalizing the designs.

The economic analysis is presented in Exhibit II-14. The yearly operating costs include maintenance, utilities, labor, and fuel. Savings result from electrical generation and value added to the kiln dried lumber. To calculate the savings from kiln operation, it was assumed that the operating cost would be $4 per 1000 board feet and labor cost was $15 per 1000 board feet. The drying cycle was assumed to last three weeks which would allow approximately 16 charges per year in each of the three kilns. Since current kiln costs are quoted to be $100 per 1000 board feet, a savings of $81 per 1000 board feet or $194,000 per year results. Gross savings by the hot air turbine system is $758,600 per year or a simple payback of 3.34 years.

EXHIBIT II-14
HOT AIR TURBINE
ECONOMIC ANALYSIS

Operating Cost	
Raw material (wood @ $7.20/ton)	$ 264,400
Labor	$ 32,425
Supervision & Clerical	$ 24,945
Utilities	$ 54,875
Maintenance & Repair	$ 54,875
Operating Supplies	$ 7,480
	$ 439,000
Direct Production Cost	
Fixed charges	$ 20,000
Plant Overhead	$ 60,000
TOTAL PRODUCTION COST ($/yr)	$ 519,000
Estimated Cost of Conventional System	
Electricity	$1,083,600
Kiln	$ 194,000
	$1,277,600
GROSS ANNUAL SAVINGS	$ 758,600
Loan Repayment	$ 504,520
NET ANNUAL SAVINGS	$ 254,080

5. ALTERNATIVE II—GASIFIER

Consideration was given to the conversion of the waste material into fuels by means of gasification. In a gasification process actually both liquid and gas fuels are produced. However, as the fuel comes from the gasifier, the liquid is either in the vapor state or as very small suspended droplets. If the fuel is utilized close to the gasifier and the design is such as to prevent condensation of the liquid, then the fuel from the gasifier can be considered totally gaseous. The advantage of converting the waste material into a gas is that this gaseous fuel could be used in existing gas burning combustion equipment without major changes in the equipment.

The present state of gasification and pyrolysis systems is that the majority of existing systems have been developed and applied to the processing of wood. While much interest and work has been directed toward the processing of other biomaterials, their commercial status is not clear. Including paper, cards, and cardboard waste in with the wood appears feasible but additional investigation would be required to establish this. The inclusion of fluff and plastic waste material in with the wood looks doubtful and it is our opinion that development and test work would be required to establish if this could be done. Therefore, simply for state-of-the-art technology as understood within the scope of this study, gasification and pyrolysis systems were considered only for the wood waste generated in the Wood Products Division. Obviously, wood waste from other sources could be included. At this stage, gasification and pyrolysis are viewed as possibilities only for utilizing wood waste and would not be applicable to the entire waste problem.

The gasification system is designed to produce a gaseous fuel from the wood waste generated by the Wood Products Division.

This waste consists of chips at 43 percent moisture, sawdust at 61 percent moisture, and bark at 35 percent moisture as described in a letter from Mr. Frank Holloday to Mr. Paul H. Butler, July 31, 1980. This combination gives a total of 141 tons/day of wood waste at 46 percent moisture. It is assumed that no hogging or grinding of the wood waste coming from the Wood Products Division is required; however, the validity of this assumption should be established. Based on this assumption, equipment for pretreatment is not incorporated in the system. It is our opinion that predrying of the waste rather than drying in the gasification process will result in a better operating and more reliable gasification system.

The wood waste is delivered to a combination holding and feed system which delivers the wood to a dryer. The system is located at CDS and uses waste heat from the Maertz Furnace or from the waste heat boiler to dry the wood. It is envisioned that this is a commercial dryer adapted to use waste heat. The analysis is based on removing 90 percent of the moisture in the wood with a heat requirement of 1800 Btu/lb of water removed. This will result in the wood exiting from the dryer at 8.5 percent moisture on a wet basis. It is felt that this amount of water removal is not necessary and that a dried wood of less than 20 percent would be satisfactory. A schematic of the system is shown in Exhibit II-15. From the dryer system the wood is delivered to a storage bin located near the west mill. This storage bin is intended to hold up to 12 hours of wood in order that delivery of wood from CDS to the west mill could occur only during the day. The aluminum melting and holding furnaces located at the Aluminum Rod Mill were identified as candidates for use of the gaseous fuel from the gasifier. It was assumed that no problems were anticipated in using this fuel in the aluminum furnaces and the fuel requirement appears to be about 25 percent higher than what would be

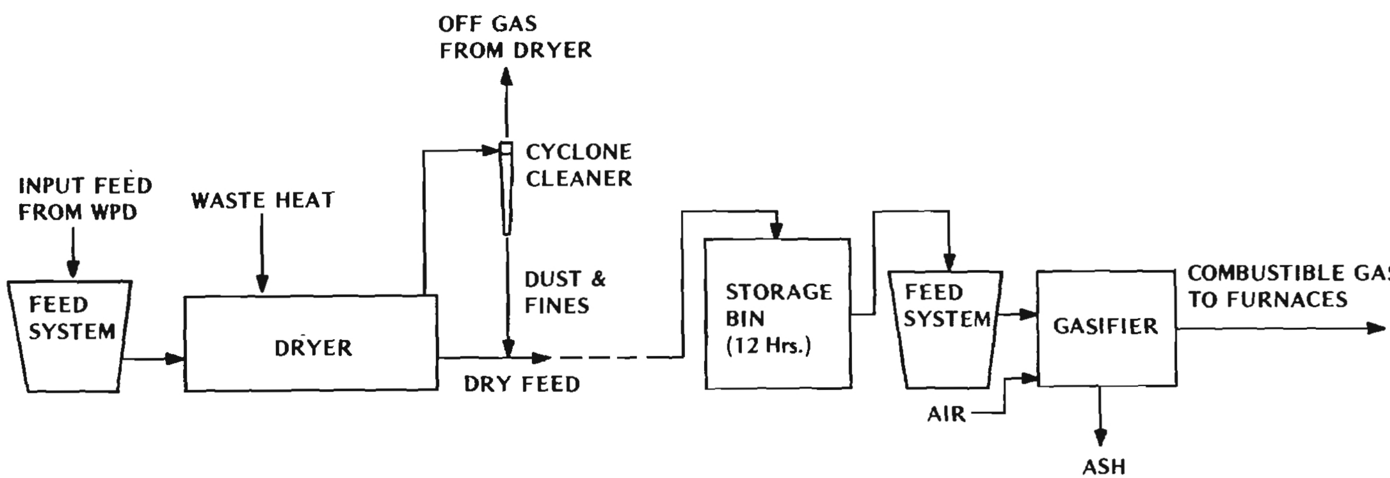


EXHIBIT II-15
GASIFIER SYSTEM

generated. This fuel requirement is based on the rated capacities of the furnaces and no evaluation was made of the impact of the furnace duty cycles. In fact it may be that at times more fuel is generated than can be used, in which case provision for disposal of the excess fuel may be required.

When this system was first considered it was understood that the fuel should probably not be used for the copper melting furnaces since the atmosphere of combustion products over the copper was very critical. However, it was later realized that this applied to the melting of refined copper and not necessarily to the melting of copper scrap prior to refining. Therefore, it would make more sense to install the system at CDS for producing fuel for the scrap copper melting furnace rather than installing the system at the west mill. This should not materially change the economics but the system located at CDS would appear to be a much better arrangement.

The system shown in Exhibit II-15 receives 141 tons/day of wood at 46 percent moisture (wet basis). It is assumed that 80 percent of the energy in this wood is recoverable in the product gas. Therefore, the gas produced has an energy value of 960 x 10^6 Btu/day, or 40 x 10^6 Btu/hr over a 24 hour period. Heating requirements for the dryer would be about 8.7 x 10^6 Btu/hr and the system would produce about 4 tons/day of ash which would require disposal.

An economic analysis for the gasifier system is given in Exhibits II-16 and II-17. For this analysis a cost of $400,000 was assumed for the gasifier. This figure was arrived at from discussions with several different gasifier manufacturers cited in Solar Energy Research Institute report SERI/TR-33-239, Volume III. In spite of the fact that this reference lists many commercial firms supposedly producing gasifiers, the availability of a commercial gasifier of guaranteed performance is highly

EXHIBIT II-16
GASIFIER CAPITAL INVESTMENT

Purchased Equipment	
Dryer	$ 100,000
Gasifier	$ 400,000
Storage System	$ 70,000
Mechanical Equipment	$ 25,000
	$ 595,000
Construction	
Piping & Mechanical	$ 50,000
Electrical	$ 40,000
Service Facilities	$ 50,000
Instrumentation & Controls	$ 25,000
Yard Improvement	$ 40,000
	$ 205,000
Indirect Cost	
Engineering	$ 150,000
Construction Expenses	$ 100,000
Total Direct & Indirect	$1,050,000
Construction Fees	$ 60,000
Contingency	$ 120,000
Fixed Capital Investment	$1,230,000
Working Capital	$ 120,000
TOTAL CAPITAL INVESTMENT	$1,350,000
20% Federal Tax Credit	$ 270,000
NET CAPITAL INVESTMENT	$1,080,000

EXHIBIT II-17
GASIFIER ECONOMIC ANALYSIS

<u>Operating Cost</u>	
Raw Material	$ 264,400
Labor	$ 250,000
Supervision & Clerical	$ 37,500
Utilities	$ 75,000
Maintenance & Repair	$ 98,800
Operating Supplies	$ 14,100
Laboratory Charges	$ 37,500
	$ 777,300
<u>Direct Production Cost</u>	
Fixed Charges (Taxes - etc)	$ 77,600
Plant Overhead	$ 190,600
Total Annual Production Cost	$1,045,500
Estimate cost of conventional system	$ 689,100
GROSS ANNUAL SAVINGS (LOSS)	$ (356,400)
Loan Repayment	$ 215,192
NET ANNUAL SAVINGS (LOSS)	$ (571,592)

doubtful. If a gasification system is to be considered and further investigations made, it is recommended that initial considerations be given to the system manufactured by Halcyon Associates, Inc., Maple Street, East Andover, New Hampshire 03231 (603)735-5356. The economic analysis is based on the best engineering judgement and considering items as outlined in the book Plant Design and Economics for Chemical Engineers, by M. S. Peters and D. K. Timmerhaus.

6. ALTERNATIVE III—PYROLYSIS

Consideration was given to the conversion of the waste material into fuels by means of pyrolysis. In a pyrolysis process the fuels produced are in three forms; solid char, heavy oils and gas. If the pyrolysis system is located very close to the equipment in which the gaseous fuel would be used then it is feasible to consider that only two forms of fuel are produced, solid and gas, since the liquids coming from the pyrolyzer are in suspension in the gases and could be burned directly with the gases. Unfortunately, this liquid contains some heavy oils that will condense at elevated temperatures and experience has taught that it is extremely difficult to prevent the deposit of heavy tars in the lines and burners. This approach is not recommended, so the heavy oil should be condensed out of the gas stream in a separate condenser.

The pyrolysis system considered is similar to the gasification system except that three forms of fuel are produced. As was the case for the gasifier, state of the art technology is such that a pyrolysis system is believed to be applicable for conversion of only the wood waste. Therefore, as before, wood waste from CDS is dried and transported to the west mill where the pyrolysis system is located. At the west mill, the pyrolysis system produces char, oil, and gas from the wood waste and the gas is utilized in the aluminum melting furnace.

As in the case of the gasifier, a better system is probably to locate the system at CDS and use the gas in the scrap copper melting furnace. The oils from pyrolysis would require temporary storage and then transportation to oil burning equipment for use. Pyrolysis oils produced by a Tech-Air Corporation plant in Cordele, Georgia were reportedly successfully burned in oil burning equipment by a local company. However, Georgia Tech experience in the handling and burning of pyrolysis oil is limited and it is a personal belief that some time and effort would be required to develop this into a trouble free operation. Although several options are open, including direct sales, no best use for the pyrolysis char was established.

The pyrolysis system is shown in Exhibit II-18. Eighty percent of the energy content of the wood feed is contained in the three fuels. Of the energy content in the fuels, one half is in the 19 tons/day of solid char or 20 x 10^6 Btu/hr, a little over one fourth in the 3000 gal/day of oil or 11 x 10^6 Btu/hr, and about one fourth or 9 x 10^6 Btu/hr in the gas. An economic analysis of the pyrolysis system is given in Exhibits II-19 and II-20. The basis of this analysis is the same as that for the gasifier. The price of $650,000 for the pyrolyzer is based on a quoted sales price for a system of comparable size by Tech-Air Corporation.

7. ALTERNATIVE IV—FERMENTATION

Dilute acid hydrolysis is the only method of converting cellulose to hexose that is close to commercialization. The hydrolysis of cellulose using dilute acid is a series first order reaction as follows:

$$\text{Cellulose} \xrightarrow{k_1} \text{hexose} \xrightarrow{k_2} \text{degradation by-products}$$[1]

1. J. F. Saeman, Ind. Eng. Chem., 37 (6) 43 (1945).

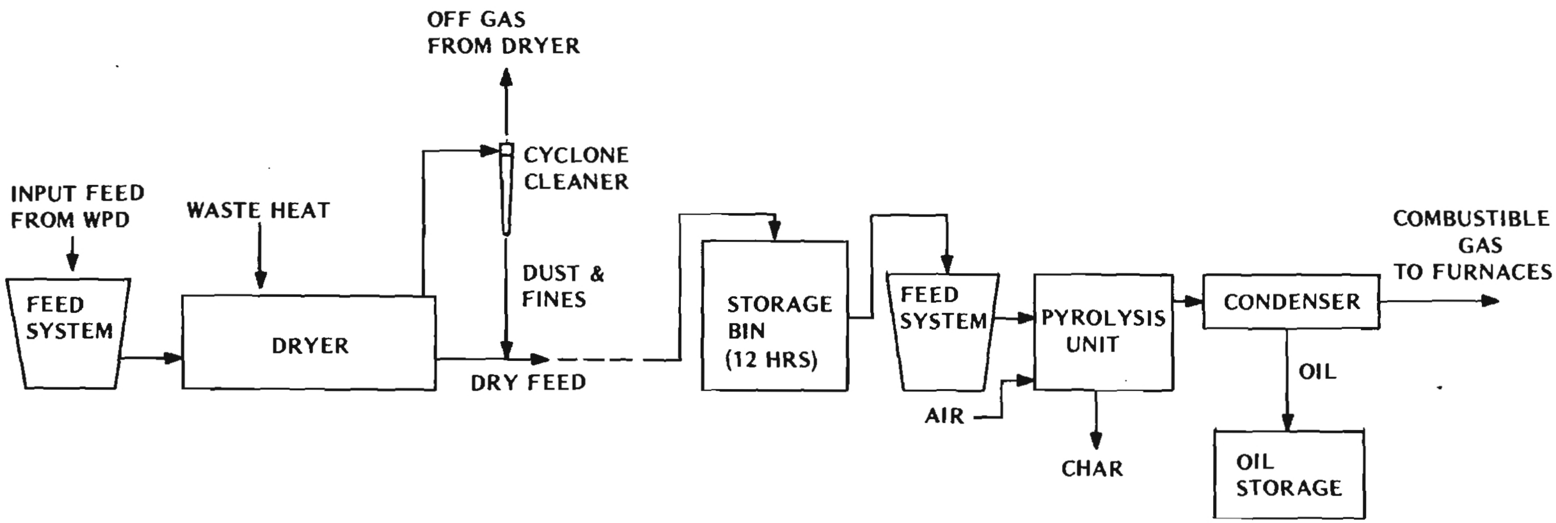


EXHIBIT II-18
PYROLYSIS SYSTEM

EXHIBIT II-19
PYROLYSIS CAPITAL INVESTMENT

Purchased Equipment	
Dryer	$ 100,000
Pyrolyzer	$ 650,000
Condenser (Scrubber)	$ 250,000
Wood Storage	$ 70,000
Char & Oil Storage	$ 50,000
Mechanical Equipment	$ 25,000
	$1,145,000
Construction	
Piping & Mechanical	$ 60,000
Electrical	$ 50,000
Service Facilities	$ 50,000
Instrumentation & Controls	$ 25,000
Yard Improvements	$ 40,000
Indirect	
Engineering	$ 200,000
Construction Expenses	$ 100,000
Total Direct & Indirect	$1,070,000
Construction Fees	$ 75,000
Contingency	$ 150,000
Fixed Capital Investment	$1,895,000
Working Capital	$ 180,000
Total Capital Investment	$2,075,000
20% Federal Tax Credit	$ 415,000
NET CAPITAL INVESTMENT	$1,660,000

EXHIBIT II-20
PYROLYSIS ECONOMIC ANALYSIS

Operating Cost	
Raw Material	$ 264,400
Labor	$ 250,000
Supervision & Clerical	$ 37,500
Utilities	$ 125,000
Maintenance & Repair	$ 190,900
Supplies	$ 28,600
Laboratory Charges	$ 37,500
	$ 933,900
Direct Production Cost	
Fixed Charges	$ 100,900
Plant Overhead	$ 239,100
Total Annual Production Cost	$1,273,900
Estimated cost of conventional system	$ 689,100
GROSS ANNUAL SAVINGS (LOSS)	$ (584,800)
Loan Repayment	$ 330,800
NET ANNUAL SAVINGS (LOSS)	$ (915,600)

A major problem is the degradation of hexose to unwanted by-products. When a single reactor is used, approximately 55 percent of the cellulose is converted into recoverable hexose. In the GIT process, excessive degradation of the hexose is prevented by first removing the lignin from the wood and then using a recycle reactor. Using this system, approximately 80 percent of the cellulose is converted into recoverable hexose[1]. Unfortunately, the GIT process is much too capital intensive for the small quantities of biomass available at Southwire. An alternative process which is less capital intensive than the GIT process was developed. In the alternative process two reactors in series are used for the cellulose hydrolysis. Computer modeling indicates that if two reactors in series are used, approximately 67 percent is converted into recoverable hexose[1].

In the proposed system, illustrated in Exhibit II-21, wood chips and sawdust are loaded periodically into a forage wagon using a front loader where a belt conveyor continuously feeds a Stake Technology reactor. An acid solution and steam are also injected into the reactor to maintain a temperature of 410°F on an acid solution of approximately 0.5 percent sulfuric acid. The reactor discharges into an agitated slurry tank. The solids are dewatered and washed using a drum filter. Solids from the filter are fed into a second Stake Technology reactor. This reactor operates at 410°F and one percent sulfuric acid. The reactor again discharges into a slurry tank filter system, with the solid residue composed mostly of lignin with a small amount of cellulose. The residue could be combusted or placed in a landfill. The acid sugar solution is

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1. D. J. O'Neil, _et al_., "Design, Fabrication and Operation of a Biomass Fermentation Facility," Technical Progress Report No. 4, DSE-3060 T-4, Distribution category UC-61 National Technical Information Service

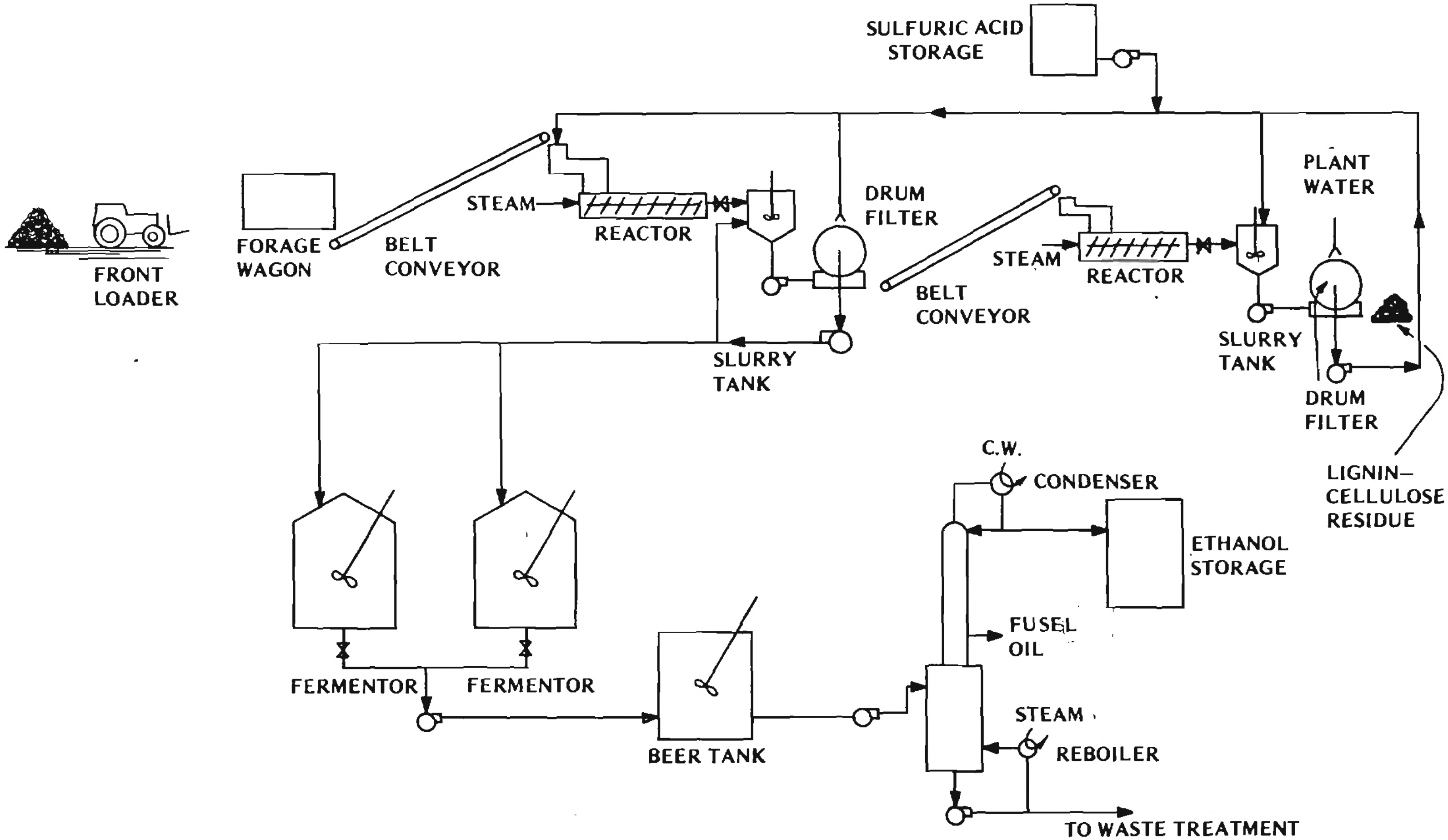


EXHIBIT II-21
FERMENTATION SYSTEM

used to wash the solids from the first reactor. The recycle configuration results in a more concentrated sugar stream than would be possible with water washing. The sugar solution is fed into one of the two batch fermentors where the sulfuric acid is neutralized by the addition of lime and ammonia. Next, phosphate and seed yeast are added. The fermentation cycle takes forty-eight hours. After completion of the fermentation the beer is fed to the beer tank. Beer is continuously pumped to the alcohol recovery still where the ethanol is separated from the slops. The slops consist of mostly yeast and calcium sulfate. The product ethanol goes to the ethanol storage tank.

Southwire has excess low pressure steam capacity; therefore, no provision was made for low pressure steam boilers or waste heat recovery boilers. A bark and lignin boiler provides the medium pressure steam required for the hydrolysis reactors.

Major equipment was sized using standard engineering practices and costed using published data or vendor quotes. A list of the purchased equipment is given in Exhibit II-22. The purchased equipment was then factored, as shown in Exhibit II-23, to give a preliminary capital investment estimate for the facility. The total capital investment was estimated to be $5,429,000. A material balance for the process is shown in Exhibit II-24. The manufacturing cost of ethanol was then estimated as shown in Exhibit II-25. The manufacturing cost of the 95% ethanol was $2.11/gallon. The current selling price of 95% ethanol is approximately $1.75/gallon. This is below the estimated manufacturing cost and thus results in no profit being generated by the facility.

A major design problem with the facility lies in the relatively small amount of biomass available for processing.

EXHIBIT II-22
FERMENTATION EQUIPMENT LIST

Unit	Basin	Unit Cost	Units Required
Front End Loader		8,000	1
Forage Wagon	500 ft^3	4,000	1
Belt Conveyor	30 ft	8,000	2
Reactor	244,000 #/day hastilloy lined, 300 psi	300,000	2
Slurry tank/ agitator	Redwood 3000 gal	8,000	2
Filter Feed Pump	304 ss, Screw	7,000	2
Drum Filter	304 ss, 100 ft^2	63,000	2
Filter Pump	304 xx, centrifugal	2,000	2
Sulfuric Acid Tank	3000 gal, cs	7,000	1
Sulfuric Acid Pump	cs	1,500	1
Fermentor	cs, coated 150,000 gal	73,300	2
Fermentor Pump	centrifugal, 40 gpm	1,800	1
Beer tank with agitator	150,000 gal, cs, coated	48,000	1
Still Feed Pump	centrifugal 40 gpm	1,800	1
Distillation column with reboiler and condenser	3,700 gpd of 95% EtOH	220,000	1
Slops Pump	12,000 #/day barks & lignin fired	4,000	1
Packaged Boiler System	400 psig, barks & lignin fired	55,000	1
	Total Purchased Equipment	$1,273,700	

EXHIBIT II-23
FERMENTATION CAPITAL INVESTMENT

Purchased Equipment	$1,273,700
Construction	
Equipment Installation	$ 496,700
Piping & Mechanical	$ 394,800
Electrical	$ 127,400
Service Facilities	$ 700,500
Instrumentation & Controls	$ 165,500
Yard Improvements	$ 127,400
Buildings	$ 369,400
	$2,381,700
Indirect	
Engineering	$ 407,600
Construction Expenses	$ 433,000
Total Direct & Indirect	$4,496,000
Construction Fees	$ 224,800
Contingency	$ 449,600
Fixed Capital Investment	$5,170,400
Working Capital	$ 258,500
Total Capital Investment	$5,428,900
20% Federal Tax Credit	$1,085,780
NET CAPITAL INVESTMENT	$4,343,120

EXHIBIT II-24
FERMENTATION MATERIAL BALANCE

SYSTEM INPUT	Weight Dry Basis #/Day
Chips	102,000
Sawdust	25,000
Bark (Steam boiler fuel)	25,000
Sulfuric Acid	3,400
Lime	2,900
Diammonium Phosphate	12
NH_3	250

SYSTEM OUTPUT	Weight #/Day
Ethanol	23,400 (3,700 gal/day 95% EtOH)
Lignin-Cellulose Residue	30,400 (Boiler Fuel)

EXHIBIT II-25
FERMENTATION ECONOMIC ANALYSIS

Operating Cost	
Raw Material	$ 338,850
Labor	$ 263,250
Supervision & Clerical	$ 27,000
Utilities	$ 135,000
Maintenance & Repair	$ 469,800
Operating Supplies	$ 47,250
Laboratory Charges	$ 27,000
Royalties	$ 67,500
	$1,375,650
Direct Production Cost	
Fixed charges	$ 233,550
Plant Overhead	$ 380,700
Total Annual Production Cost	$1,989,900
Market Value of Product	$2,362,500
GROSS ANNUAL INCOME (LOSS)	$ 372,600
Loan Repayment	$ 865,375
NET ANNUAL INCOME (LOSS)	$ (492,775)

Note: Based on 1.35 million gallons of alcohol per year.

If additional low or zero cost biomass were available, the process may become profitable. Until additional low cost biomass is available or new technology is available, the manufacture of ethanol from wood residues at Southwire is not considered to be economically attractive.

III. SYSTEM EVALUATION

Each of the alternative systems described in Section II was evaluated to assess the economic feasibility and potential risk associated with it. The economic data developed previously is summarized in Exhibit III-1. The annual capital cost represents payments on a ten-year loan at 15 percent interest. Savings depict the value of conventional energy displaced or, as in the case of alcohol, the market value of the product. While a reasonable amount of effort was expended to assure comparable cost figures for each alternative, some minor discrepancies exist due to the diverse technology of the systems, but they did not affect the outcome of the evaluation.

Traditional measures of system effectiveness relating to product quality are not very meaningful when applied to an energy system. The dominant criterion is system performance. Specifically, does it work? To estimate the likelihood of an alternative system functioning properly, six factors were felt to be important contributors to risk:

- Technology development stage
- New application
- Complexity
- Potential maintenance problems
- Waste disposal
- Additional feedstocks required

New technology demonstrated in a prototype model has substantially greater risk of problems than an alternative system that has performed satisfactorily for many years.

EXHIBIT III-1
ECONOMIC ANALYSIS SUMMARY

	Annual Cost—Alternative System					Annual Cost Existing System	Net Annual Savings
	Alternative	Capital	Operations	Fuel	Total Cost		
IA	Wet Cell	$140*	$ 194	$302	$ 636	$ 917	$ 281
IB	High Pressure Boiler	185	189	267	641	742	101
IC	Low Pressure Boiler	121	121	264	506	689	183
ID	Hot Air Turbine	505	255	264	1,024	1,278	254
II	Gasifier	215	782	264	1,261	689	-572
III	Pyrolysis	331	1,010	264	1,605	689	-916
IV	Fermentation	865	1,727	264	2,856	2,363**	-493

*Figures are in thousands of dollars

**Market value of ethanol produced ($1.75/gallon)

Similarly, utilizing a process in a new application has greater risks than opting for the standard practice. Complexity and potential for maintenance problems are expected to exhibit a high correlation with down time and hence risk. Waste disposal and feedstock procurement introduce uncertainties associated with government regulations, procurement, and inventory maintenance. The relative importance of each factor was estimated and is shown in Exhibit III-2.

The next step in risk determination was to evaluate each alternative system utilizing the criteria previously developed. An alternative system was rated on a scale of zero to ten for the perceived risk affiliated with each factor. These results are tabulated in Exhibit III-3. Finally, the weight of a factor was multiplied by the score of an alternative system on that factor and then summed across all factors to arrive at a composite risk score for each alternative. The final risk estimate is included in Exhibit III-4, with higher numbers representing greater risk.

System evaluation results are displayed graphically in Exhibits III-5 and III-6. The first of these depicts annual savings as a function of cost, while the second shows risk as a function of cost.

EXHIBIT III-2
RELATIVE IMPORTANCE OF
RISK FACTORS

Factor	Weight
Technology Development Stage	35
New Application	20
Complexity	20
Potential Maintenance Problems	15
Waste Disposal	5
Additional Feedstocks Required	5
Total	100

EXHIBIT III-3
RISK EVALUATION

	Alternative	Technology Development Stage	New Application	Complexity	Potential Maintenance Problems	Waste Disposal	Additional Feedstocks Required
IA	Wet Cell	2	4	2	2	1	1
IB	High Pressure Boiler	0	1	4	4	1	1
IC	Low Pressure Boiler	0	0	1	2	1	1
ID	Hot Air Turbine	6	8	6	6	1	0
II	Gasifier	6	4	4	6	1	0
III	Pyrolysis	7	8	6	6	2	0
IV	Fermentation	8	4	7	4	3	5

Note: Larger numbers indicate greater risk

EXHIBIT III-4
RISK SCORES

	Alternative	Aggregate Risk
IA	Wet Cell	230
IB	High Pressure Boiler	170
IC	Low Pressure Boiler	60
ID	Hot Air Turbine	585
II	Gasifier	465
III	Pyrolysis	625
IV	Fermentation	600

EXHIBIT III-5
COST-SAVINGS SUMMARY

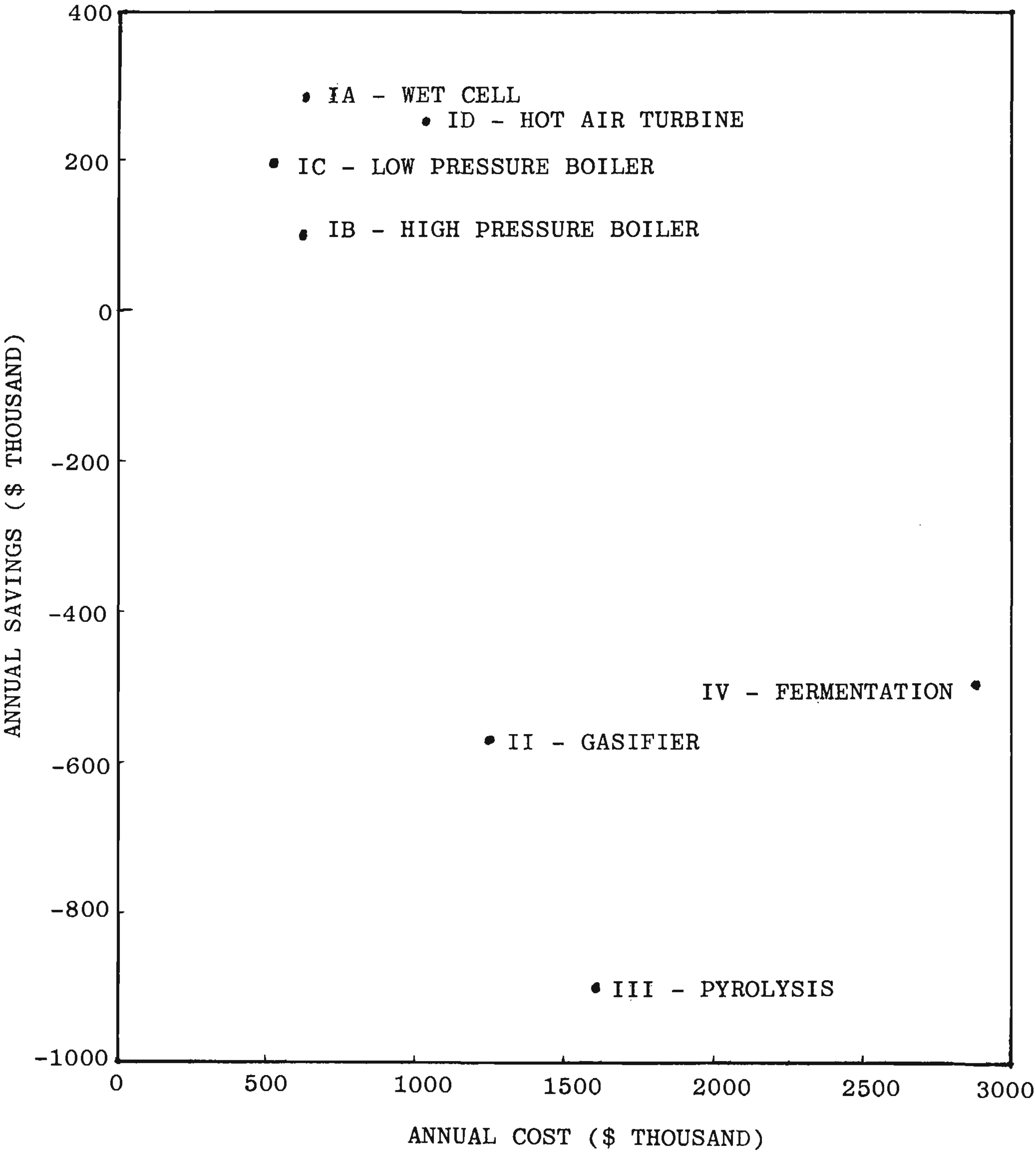
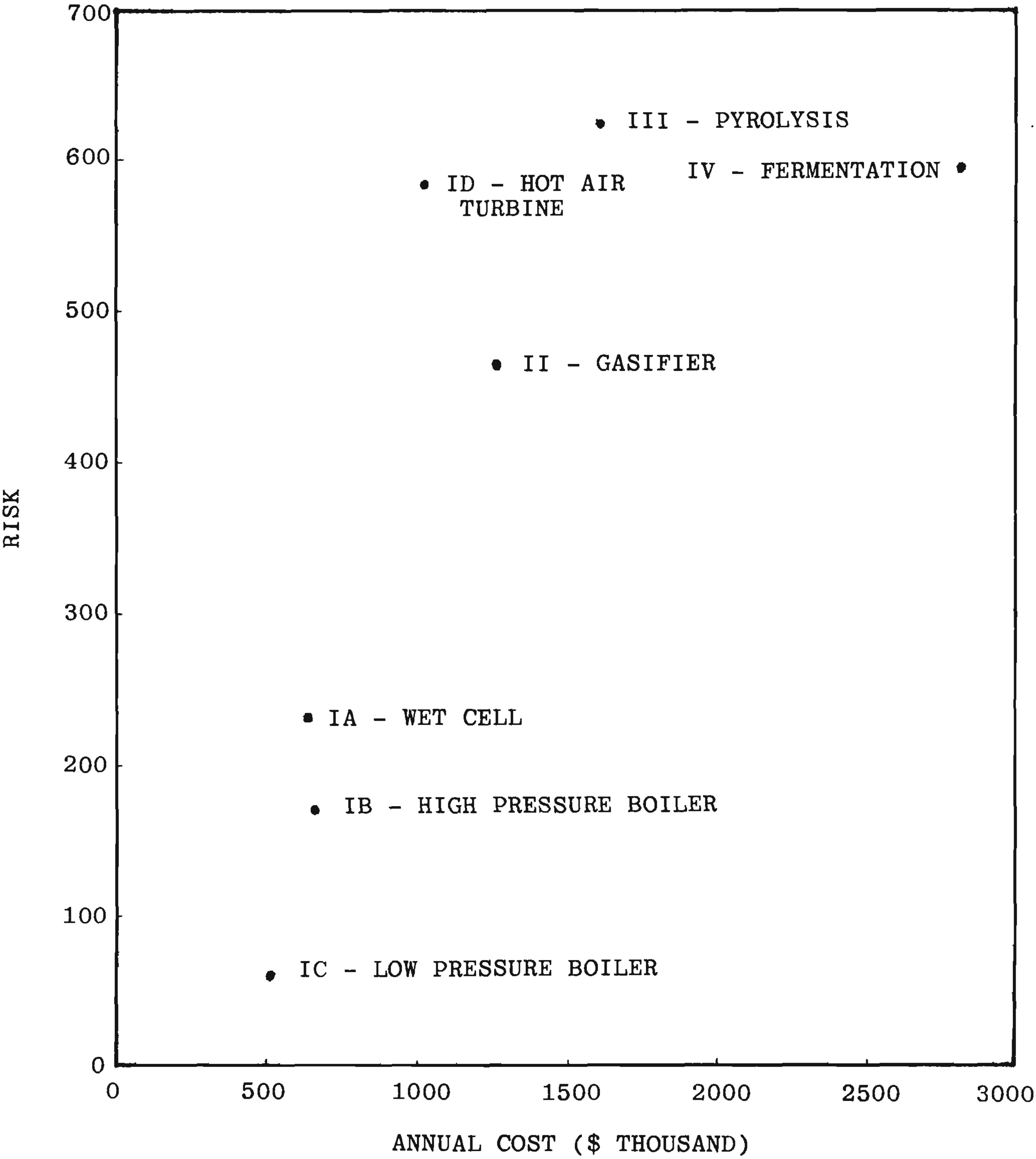


EXHIBIT III-6
COST-RISK SUMMARY



IV. RECOMMENDATIONS

Based on the system evaluation documented in Section III, the gasifier, pyrolysis, and fermentation alternatives would lose substantial sums of money, hence should receive no further consideration at this time. The dominant reason for this is that these systems are not economically viable in the small size required for the Southwire plant.

In the remaining alternatives, a conservative business approach would indicate the use of the Low Pressure Boiler option. While not very glamorous, it has the lowest risk and a good cash return. The largest annual savings is obtained with the Hot Air Turbine and Wet Cell alternatives. Unfortunately, they are innovative systems which entail significant risk. If some form of government funding were available to help offset the risk incurred by Southwire, they would be alternatives worth pursuing and would receive our recommendation. These alternative systems should be attractive to a government agency since wood waste is readily available in much of the United States, and the electrical and thermal energy produced are readily usable by a wide variety of industrial plants.

In summary, it is recommended that Southwire seek government participation in the implementation of the Hot Air Turbine or Wet Cell alternatives as the best method of utilizing the waste wood for overall energy conservation. If this support cannot be obtained, Southwire should consider implementing the Low Pressure Boiler alternative system.